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Psychophysical threshold measures were used in combination with precisely located lesions of the sub-cortical visual pathway to examine segregation of function between P and M pathways. Scleral search coils monitored fixation locus in the tested monkeys, to insure that test stimuli were presented in visual field regions corresponding to the lesion location. Results of these studies indicated that the P pathway (or color-opponent pathway) is the major contributor to visual acuity, color vision, and luminance contrast sensitivity. On the other hand, the M pathway (or broad contours), as well as sensitivity to rapidly drifting visual stimuli. A special role for the M pathway in the processing of visual motion was ruled out by determining its contribution to directional and velocity sensitivity

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1. Abstract

Psychophysical threshold measures were used in combination with precisely located lesions of the sub-cortical visual pathway to examine segregation of function between P and M pathways. Scleral search coils monitored fixation locus in the tested monkeys, to insure that test stimuli were presented in visual field regions corresponding to the lesion location. Results of these studies indicated that the P pathway (or color- opponent pathway) is the major contributor to visual acuity, color vision, and luminance contrast sensitivity. On the other hand, the M pathway (or broadband pathway) appeared crucial for the visibility of low spatial frequencies (broad contours), as well as sensitivity to rapidly drifting visual stimuli. A special role for the M pathway in the processing of visual motion was ruled out by determining its contribution to directional and velocity sensitivity.

2. Research objectives

The goal of this project was to determine if there is a segregation of function between the sub-cortical P and M visual pathways of the macaque. Lesions were made by the injection of ibotenic acid (a glutamate agonist) into carefully selected regions of the parvocellular and magnocellular layers of the lateral geniculate nucleus. Visual function was assessed by the measurement of psychophysical thresholds in portions of the visual field corresponding to the lesions.

3. Status of the research

As part of our assessment of the pre-lesion vision of two monkeys, we determined spatial resolution across the horizontal meridian of the visual field. As was expected from preliminary results in humans, acuity declined monotonically with distance from the fovea. The rate of this decline, and the absolute acuity at each eccentric location were in close agreement with the resolution limits imposed by sampling density of retinal ganglion cells of the P pathway. Later results (below) on the effects of lesions of the P pathway on visual acuity confirmed that the P pathway limits visual acuity.

In initial studies, lesions were made in the parvocellular layers of the lateral geniculate of two monkeys. Psychophysical testing was followed by physiological and anatomical reconstruction of the lesion. Fortunately, both lesions fully destroyed the parvocellular and spared the magnocellular layers in the region corresponding to the tested locus in the visual field. Results of these studies showed clearly that the P pathway plays a dominant role in spatial resolution and chromatic contrast sensitivity as well as luminance contrast sensitivity over a broad range of spatial and temporal frequencies.

Determining the effect of M pathway lesions on visual function has proven to be somewhat more complex. In our first studies, we found that temporal resolution was not reduced by lesions of the M pathway. This result was somewhat counter- intuitive, since visual system physiologists have generally considered the M pathway to be the basis of temporal resolution. Effects on contrast sensitivity were consistent with the findings for temporal resolution. Low spatial and higher temporal frequency vision was devastated by M lesions. However, at moderate or higher spatial frequencies, lesions of the M pathway had no measurable effect on contrast sensitivity.

More recently we studied the role of the M pathway in motion processing by testing direction discrimination and velocity difference thresholds after M lesions. These studies showed that the M pathway is not uniquely capable of the processing that underlies motion perception. These results challenge recent suggestions that the M pathway may mediate motion perception.

In parallel with this work we completed a study, using the acrylamide retinal P cell degeneration model, of the role of the P pathway in acuity, vernier acuity, contrast discrimination, and shape perception. This study showed that only visual acuity of these four capacities was dependent on the integrity of the P pathway.

Our more recent work, supported since the end of the AFOSR grant by the National Eye Institute, has concerned contributions of identified cortical areas in visual processing. Our initial studies have examined areas V1, V2, V4, and MT in functions as varied as acuity, contrast sensitivity, color vision, motion processing and texture discrimination. Preliminary findings, already presented in abstract form at several meetings, indicate that basic visual detection is little affected by lesions of areas beyond V1, but that more complex functions, thought to be specific to particular extrastriate areas are affected.

4. Publications

Merigan, W.H. and Katz, L.M. (1990) Spatial resolution across the macaque retina. *Vision Res., 7,* 985-991.

Merigan W.H., Maunsell, J.H.R. (1990) Macaque vision after magnocellular lateral geniculate lesions. *Vis. Neurosci., 5,* 347-352.

Merigan, W.H., Katz, L.M. and Maunsell, J.H.R. (1991) The effects of parvocellular lateral geniculate lesions on the acuity and contrast sensitivity of macaques. *J. Neurosci., 11,* 994-1001.

Merigan, W. H. (1991) P and M pathway specialization. in: Valberg, A. and Lee, B.B. (Eds.), *From Pigments to Perception.* New York:Plenum Press.

Merigan. W. H., and Maunsell, J.H.R. (1991) Does primate motion perception depend on the magnocellular pathway? *J. Neurosci., 11,* 3422-3429.

Lynch, J.J., Silveira, L.C.L., Perry, H., and Merigan, W.H. (1992) Visual effects of damage to P ganglion cells in macaques. *Vis. Neurosci.,* (in press).

Merigan, W. H., and Maunsell, J. H. R., (1992) How parallel are the primate visual pathways? *Ann. Rev. Neurosci.,* (in press).

5. Participating personnel

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6. Oral presentations and conferences

Merigan, W. H., Pasternak, T., Polashenski, W., and Maunsell, J. H. R. (1991) Permanent deficits in speed discrimination after MT/MST lesions in a macaque monkey. *Invest. Ophthalmol. Vis. Sci., (Suppl.), 32, p. 824.*

Pasternak, T., Maunsell, J. H. R., Polashenski, W., and Merigan, W. H. (1991) Deficits in global motion perception after MT/MST lesions in a macaque. *Invest. Ophthalmol. Vis. Sci., (Suppl.), 32, p. 824.*

Nealey, T. A., Maunsell, J. H. R., and Merigan, W. H. (1992) Visual function after a lesion of cortical area V2 in the macaque. Invest. Ophthalmol. Vis. Sci., (Suppl.), 33, p. 1130.

7. Discoveries and inventions

None

8. Significance of acomplishments

Our earlier studies, proposed in the original application, and supported by AFOSR to completion, showed that subcortical visual pathways in the macaque, and possibly in the human, are quite independent, and appear specialized primarily for the transmission of different portions of the spatio-temporal visual specturm. In addition, the P pathway appears to be the sole conduit for color vision.

More recent work indicates that while cortical areas are not quite as independent as the subcortical P and M systems, both hierarchical and parallel specializations are evident in the results of lesion studies. These studies will help drive our understanding of cortical visual processing, including such issues as the number of orthogonal representations in visual cortex and the segregation/cooperation of local processing.